2K11 Krug (SA-4 Ganef)

The 2K12 Krug (SA-4 Ganef) was the first fully mobile radar guided SAM system in the USSR it was developed by the NII-20 bureau during the leadership of V.P. Efremov. The Krug was revolutionary in many areas and considered unique during the whole Cold War in many technical solutions and capabilities.

Because of some unique features regardless in some aspects was outdated even in late '70s never was exported outside the Warsaw Pact. It had unique features against anti-radiation missiles and tactical ballistic missiles. The Krug system used radio command guidance similar to older PVO and army air defense SAMs but a way is used made it totally different.

Krug was the first Soviet SAM system which used the monopulse target tracking method and had an built in analogue computer. It was fully NBC (Nuclear Biological Chemical)[1] protected by filtered over-pressurization system. The Krug was capable of firing only 5 minutes after stopping in the age were Dvina or Volkhov relocation and deployment time was measured in hours. The Soviet Union fielded the first version in 1964. The Krug was constantly improved during its lifetime resulting in the Krug-A, Krug -M and finally the Krug -M1 variants.

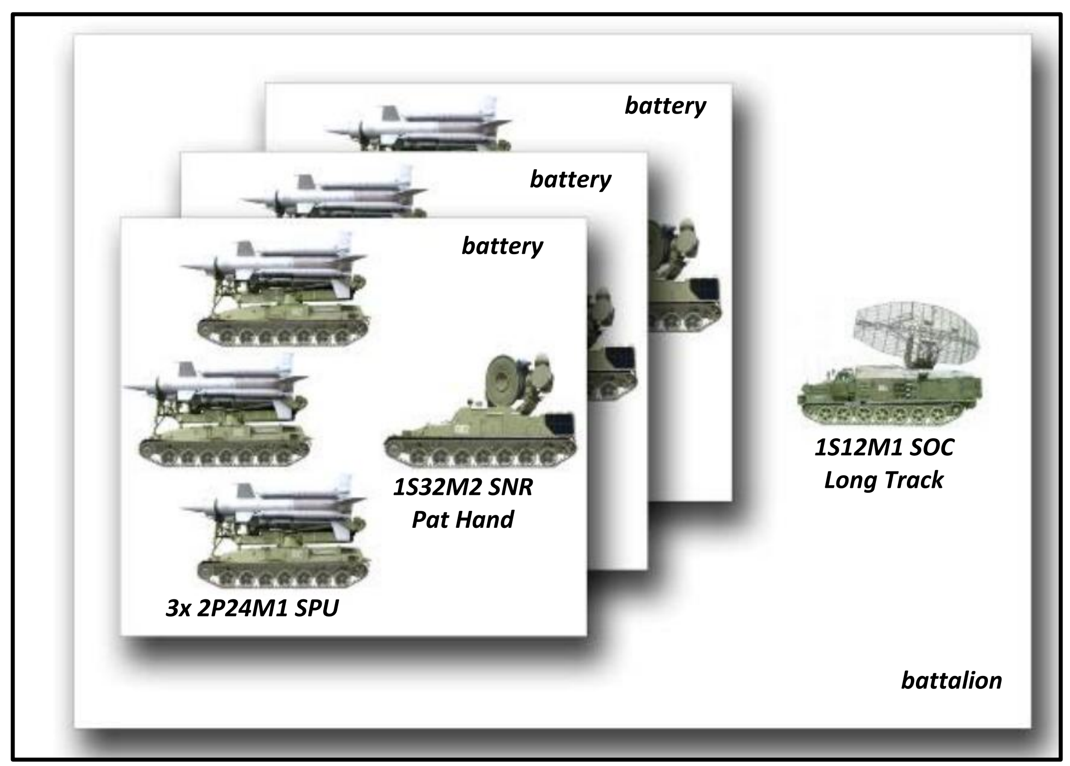
The most smallest element of the Krug brigade (or regiment) is the battery. One battalion has three batteries. One Krug brigade has three battalions, one regiment has two. The main equipment of the Krug-M1 systems are the followings:

- 1S12M1 SOC (Long Track) self-propelled long range target acquisition radar, 1x for each battalion
- 1S32M2 SNR (Pat Hand) self-propelled mobile fire control radar, 1x for each battery
- 2P24M1 SPU self-propelled mobile missile launchers 3x for each battery, 2x3M8(M3) missiles on each launcher
- P-40[2] long range target acquisition radar, 1x for each regiment or brigade
- PRV-16 (Thin Skin) heightfinder radar, 1x for each regiment or brigade

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[1] *As every army air defense system which was developed later.*

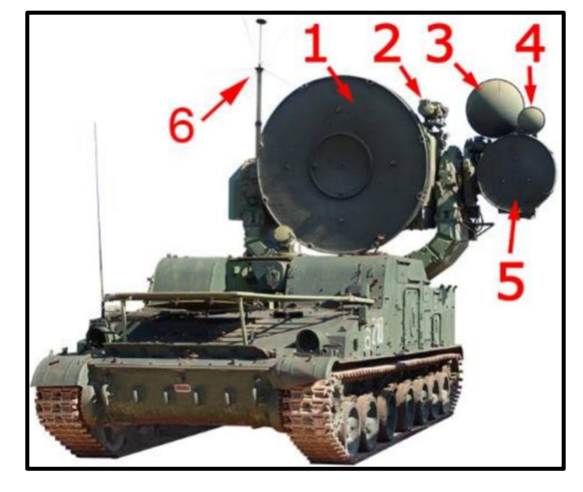
[2] *The 1S12M1 should not be mistaken with the P-40. Regardless their appearance are very similar they are on totally different organization levels. P-40 is (was) the long range target acquisition radar of the whole Krug regiment or brigade the whole unit has (had) only one. On regiment or brigade level the P-40 worked with PRV-16 heightfinder radar while the battalions did not have heightfinder radar beside the SOC. P-40 also was used for fighter guidance by the radio-technical units. It is very sad that **almost all sources** refers them as they were the same...*



Above is a Krug battalion with three batteries A brigade has three of such battalions a regiment has only two. (Hungary instead of full unit used only 2/3 of a brigade and it was called regiment.)

The 1S32M2 SNR fire control radar (guidance station) has the following antennas:

1. AVS-I monopulse target tracking antenna. (RPC)
2. TOV camera (optical target tracking)
3. SPK missile command transmitter antenna (called "RPK," Russian acronym for Radio Command Transmitter).
4. AVS-II wide beam missile tracking antenna (receive only).
5. AVS-II narrow beam missile tracking antenna (receive only).
6. retractable antenna of the 1S62 and 1S63 wireless digital data link system.

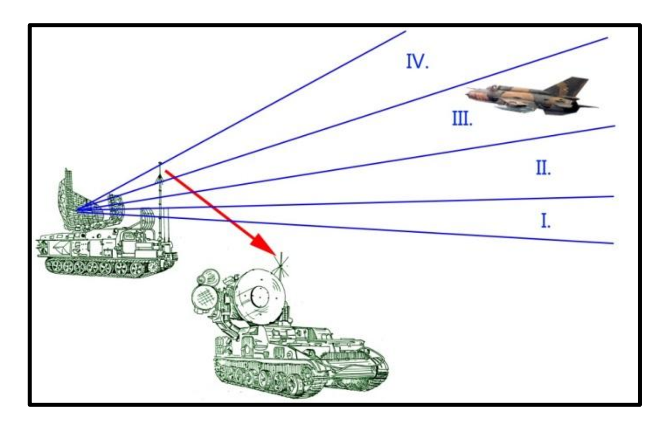


We can see the 9K33 Osa inherited many designs and technical aspects of the Krug. Comparing to the Diva and Volkhov (SA-2 family) one of the major improvement was guidance and leading method. The Krug (SA-4) was the first Soviet SAM system with independent target (AVS-I) and missile (AVS-II) tracking radars. Because of this new antenna design it could guide the missile against the target with larger lead angle than the earlier eastern systems which provided much optimal trajectory (less G demand in turns) and made possible to intercept ballistic missiles up to 800 m/s speed.

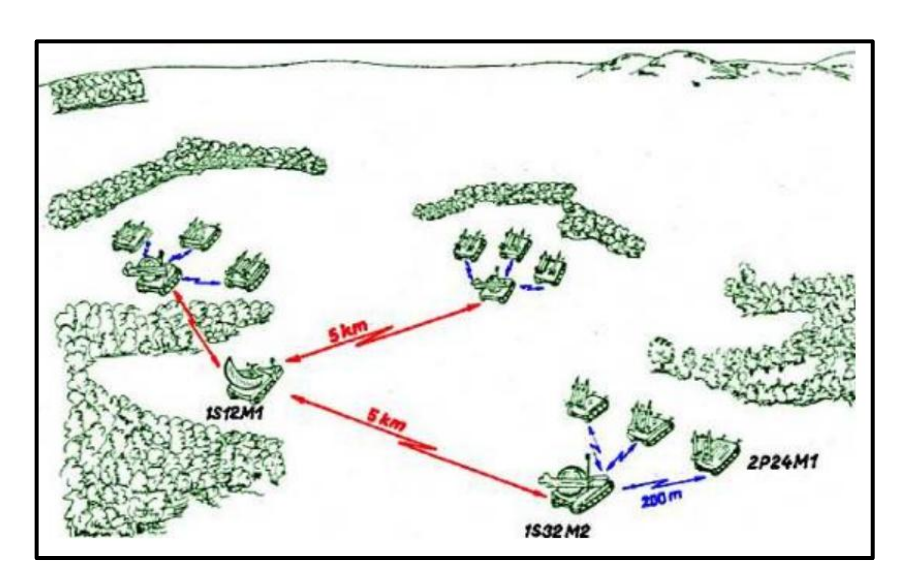
The target is tracked with the '1' labelled antenna, RCG signals are emitted with the '3' labelled antenna and the transponder signals from the missile are received with '4' and '5' antennas. As we have seen in the chapter of Osa following the missile launch the wide beam antenna is used at longer distances the narrow beam antenna takes over the role. Against smaller size targets (MiG-21, F-104, F-5) the SNR detection range is about 70-80 km the maximal displayed range on the scope is 110 km.

Target tracking above 110 km is not possible. The tower of the SNR can be turned ± 320 degrees but full rotational is not possible (similar to Osa).

For target acquisition each battalion has the 1S12M1 SOC radar but in case of need very limited and slow search is also possible with the 1S32M2 SNR guidance station by using its monopulse target tracking antenna (‘1’). The UHF band SOC nominal detection range against fighters is about 200 km. The SOC is connected to the SNR with 1S62 digital wireless datalink antenna or P-274 cable telephone connection.



By consecutively scanning four elevation sectors (I., II., III., IV.), the 1S12M1 SOC radar is capable of acquiring not only the range of the target and direction but also the approximate elevation. This can then be passed across the 1S62 wireless digital data link to the 1S32M2 SNR. (SOC of the 9K33 Osa inherited this altitude estimation capability too from the Krug.) By using the digital wireless datalink the deployment distance between the SOC and SNR can be 5 km.

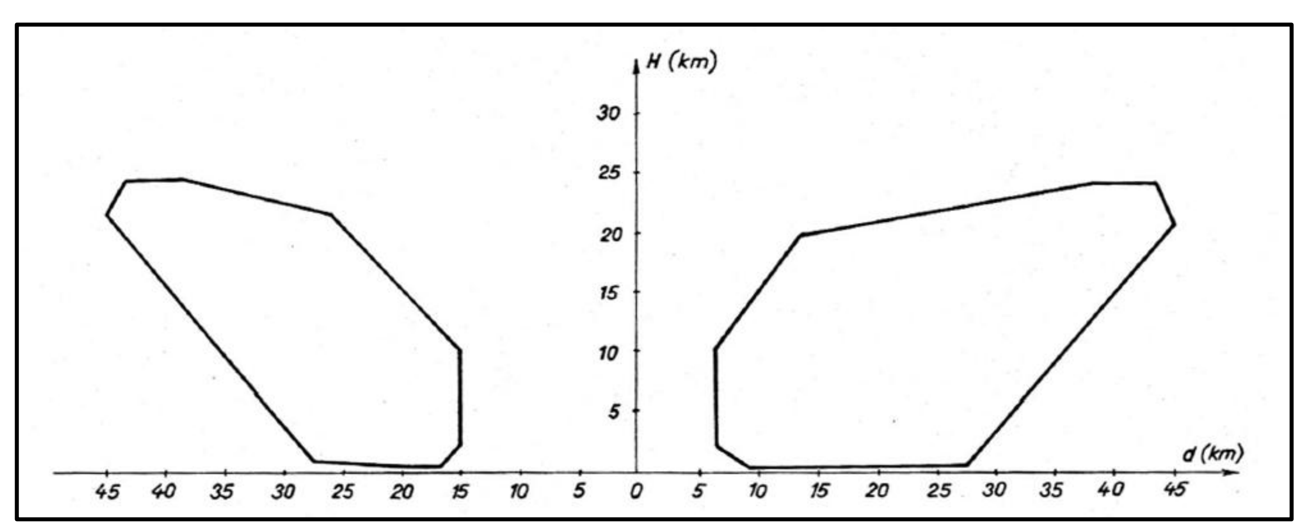


The SNR processes automatically the data from the SOC and following a short scan in elevation and azimuth automatically tracks the designated target. The further activity of the SNR is handled by the analogue computer (SRP) which calculates the numerical parameters of the engagement zone as well as the azimuth and elevation settings of the antennas and finally the direction of the missile rails of the SPUs. The SPUs receive the data via internal datalink. Following the targeting processes antennas and the launcher(s) are set towards to the target.

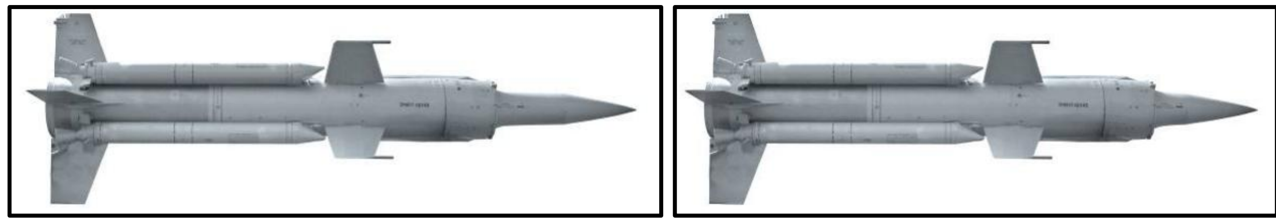
When the target enters into the launch zone (which is not the engagement zone) the missile can be launched the commander of the battery select the missile and gives the order for the launch. Following the launch missile enters into the gate zone where the wide beam antenna (‘5) intercept the missile and guides into the narrow beam (‘4) antenna’s lobe.

Using the received data from the missiles trajectory is corrected by the SNR. The warhead is armed only in terminal phase as well as the radio proximity fuse.

The 2K11 Krug has only a single target and single missile channel which means in this area is a step backward comparing to Dvina or even Neva in this area which had at least three and two missile channels. Maximal target speed was 800 m/s, maximal engagement altitude was 24.5 km up to 50 km distance.



Engagement envelope of the Krug-M1 in case of 0 km parameter (offset) distance against incoming (above right) and receding (above left.)



Above left is the 3M8 missile above right is the 3M8M3 variant the difference is minor but important at the nose section.

The missile of the Krug is still partially similar to PVO SAMs. The missile still was designed with two stages with solid propelled boosters and the main engine still was liquid propelled. For a highly mobile army air defense system was unacceptable the very toxic liquid fuel of the Dvina/Volkhov because in road and other accidents during the frequent relocations, therefore another type of liquid propellant had to be used for safety reasons. The missile use kerosene fuel.

The burnout time of the booster stages is about 4 second the main engine has about 65-72 seconds the burnout speed is about 800 m/s depending on the altitude and the trajectory. The main engine is ramjet engine which had serious impact on the maneuverability of the missile because of its design prevented the high angle of attack turns which limited the available maximal G in turns. For the 3M8 missile variant 4G was the maximal even the redesigned and upgraded 3M8M3 missile was capable to only 6G turns.

The launch weight of different missile variants is almost the same about 2450 kg which makes similar in size and weight to missiles of the S-75 Volkhov. It is worth to note and compare 9M8M3 to missile of the Kub-M3's 3M9M3 missiles. The latter has about half size engagement zone but the weight of the Kub's missiles is only the quarter of the Krug's. The radio command guidance demanded huge 150 kg warhead because its accuracy decreases with target distance. Because of the solid propelled, the non

jettisoned first stage, the SARH guidance and less range the 3M9M3 is much smaller but far more smaller and lighter proportional as is excepted by first look.[3]

One of the unique feature of the 2K12 Krug it's anti ballistic missile (ABM) capability against short range tactical ballistic missiles such as MGM 52 Lance of the French Pluton. Their terminal velocity was within the limits of the Krug and leading was possible because of the independent target and missile tracking radars.[4]

Another unique capability which could be a well utilized feature the way as the SNR and the SOC worked, the Krug can be called and "analogue LPI"[5] SAM system. [6] In case of Programmed Target Tracking ("ПНС") the AVS-I is not radiating and the antenna tower is controlled by the built-in SRP (onboard analogue computer) comparing target location data from the 1S12M1 SOC (Long Track). The forecasted (extrapolated) trajectory by the computer is compared to what the SOC measures. If the difference is larger than 7 km the SNR for a moments illuminates the target to measure accurate location of the target and be able to correct the trajectory of the missile. If the target does not (or cannot) detect the radiation from the SNR and does not make any defensive maneuvers (turns) the continuous illumination by the SNR using the AVS-I antenna is not required. This is why is can be called "LPI" the SOC uses different wavelength then the SNR therefore the target is not aware of the missile launch.

During the Periodical Illumination Target Tracking Mode the SNR is silent for a period which is calculated by the SRP (onboard analogue computer). The SNR is on the air (to update the target's path) only the shortest required time by the monopulse method around only 1 second. While the SNR is silent it cannot be detected by the enemy's RWR (Radar Warning Receivers), and cannot be shot at with ARM for example AGM-88 HARM. Regardless the AGM-88 is so advanced it can use the sidelobe of the radars if the radar is silent is not any lobe.

During the Operation Allied Force in 1999 became obvious even the AGM-88 has memory and tried to "memorize" the location of the target in case goes silent the probability of hit even the best ARM in that era was surprisingly low. AGM-88 HARMs mostly missed their targets in case the radars were turned off enough soon. (Suppression mostly was achieved but destruction was not.) If the SNR is online and emits only for very short time (about 1 sec) and in random moments the task for ARMs is really, really hard comparing to any Cold War era SAM system.

Considering the features of Krug we can say it is a very contradictory SAM system. During the '60, the '70s and against many airplanes in the '80s the detection of the missile launch could be very problematic with RWR. Even the Krug was the child of early '60s in electronic warfare the very short SNR usage made it still not so bad or even compared to the modern systems.

[3] *Hungary bought later the 2K11 Krug then the 2K12 and because of liquid fuel and much complicated system and limited support from the USSR the Krug was mostly disliked by its crew regardless of much larger engagement range. In Czechoslovakia interestingly the case was opposite they mostly liked the Krug.*

[4] *They only Hungarian unit (in Keszthely) never practiced against imitated BM targets.*

[5] *low probability intercept http://www.radartutorial.eu/02.basics/LPI%20radar.en.html*

[6] *See in the manual of 2K11M1 Krug-M1 Simulator by Hpasp.*

If the launched missile cannot be detected visually by the pilot the Krug could mean a serious threat for any airplane even the maneuvering capability of the missile was ridiculously weak comparing to any SAM systems. If the pilot cannot see or detect any way the incoming missile the task is simple for the Krug, a non maneuvering airplane is the target.

The problem for the Krug if the pilots can spot the missile it was literally easy to dodge it. Even the maximal 6G of the 9M8M3 missile was similar to first version of the SA-75 Dvina at late '50s and mid '60s while all later developed system reached about 10G (S-75M Volkhov, S-200V Vega), 12G (S-125M Neva below 10 km) and 15G (2K12 Kub) against tactical fighters at the most typical combat altitudes.) Of course is very hard to detect in many cases the missile regardless of its strong smoke trail.

Assuming the worst if the short period emission of the SNR can be detected by RWR the task is more easier for pilots as long as the main direction of the threat is known. During Vietnam similar or slightly more agile missile evaded by American pilots with. The missiles of the Dvina has similar max. G limits as the 9M8M3 missile. With the first 9M8 missile wit 4G maximal turning capability for any tactical airplane is child's play to dodge the incoming missile as long as they have speed and altitude. With Dvina and Neva was possible to make harder the evasion by launching three or two missile salvos but with single fire channel of the Krug this was not possible.

Regardless how shiny it looks on paper LPI capability its effectiveness is partially questionable because it demands the continuous operation of the SOC. Because the SOC and SNR are quite close to each other in case the more easier detectable SOC in located by RWR any pilot can be sure about direction of the main threat. The maximal distance between the SOC and SNR is 5 km. From 50-60 km distance in worst case about a 10 degree wide zone is where missiles can be expected.

For being aware of launch has to be know the operation of the SOC but checking visually the airspace towards to the SOC considerably increases the chance to spot visually the incoming missile. Of course this aid is much less comparing to a functional RWR. The SOC uses dm wavelength which is not the best for RWR of tactical airplanes because they are optimized against cm wavelength fire control radars. The SOC is detectable easier rather for electronic warfare assets.

Considering all the factors above we can say tactical airplanes in some cases could be easily avoid missiles in some not but we can say more safely with AGM-45 Shrike it was close to impossible to destroy the SNR because of its very short and intermittent emissions and the narrow beam antennas comparing to wide beam Dvina in Vietnam.

The problem is the SOC continuous operation. The PVO SAMs used the P-12/18 target acquisition radars with meter wavelength they were immune to any ARMs. Even during the Allied Force in 1999 Zoltan Dani sometimes used the P-18 for 12-24 hour period while the SNR-125 was limited to about 21 second.

The SOC used dm wavelength which could be attacked even with AGM-45[7] from close and with AGM-88 from literally any direction. Of course going close to a Krug battery is not so easy because of the layered Soviet army air defense but in general but the anti-SEAD capability of the Krug was seriously was reduced with arrival of the AGM-88 in the mid '80s. The SA-4 was phased out until and of '90s because of its archaic design and collapse of the USSR and end of Cold War.

[7] *http://www.designation-systems.net/dusrm/m-45.html AGM-45 had seeker in cm wavelength.*

Another problem was the more advanced and powerful fighters. Against 4th generation fighters the maneuvering capability of the missile became totally inadequate which in combing with HARM made more obsolete the system. Without the SOC the SNR had to be used for target search which is very suicidal in era of HARM and its search capability is close to 0 comparing to SOC.

Of course it has to be noted that AGM-88 at the end of Cold War was still almost exclusively used by the USA in the NATO other members acquired considerable quantity only after end of the Cold War even the USA still used the AGM-45 during the Operation Desert Strom in 1991.